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ABSTRACT

Even in schools where there is a strong push to adopt and use technologies, the road to content fulfillment is a long one. The technology learning curve tends to eclipse content learning temporarily--both students and teachers seem to orient to technology until they become comfortable. This dilemma has important implications for teachers' willingness to adopt technology. Content learning does emerge and is very rich once the technology recedes as the focus of activities in the classroom. However, content integration takes time, software glitches and poor student work habits can cause huge delays, and the "flash over substance" phenomenon regularly occurs as students and teachers alike are excited by the presentation capabilities of the new media. Throughout the technology adoption process, teachers tend to worry about content, feel accountable for it, and notice when it is missing. Teachers response to this key dilemma in the technology adoption process in at least three ways: diminishing or stopping technology use temporarily to make sure students accomplish content; sticking to one technology or using only the technology capabilities with which they are comfortable, and plunging head first with students, hoping to learn with them about technology. With the right support and access, all of these problems tend to recede as teachers and students gain experience with technology. To further characterize this critical tension between technology learning and content learning, this paper offers cases from two projects by the Institute for Research on Learning (Menlo Park, California). In both cases, teachers handled the technology/content dilemma and moved content learning to the foreground of activities with computer technology. (AEF)

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The Technology/Content Dilemma

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The vision is enticing. Computer technologies become the norm in schools that are equipped with multimedia, graphics and animation, access to Internet and hand-held and remote devices. There is seamlessness of learning activities among home, school and community settings. Students use technologies like they use pencils, books and manipulatives to learn content in all of the subject areas. Learning goes beyond skills and facts, and students develop thinking and problem solving skills. The world is their classroom. In this vision, technologies help students gain mastery of content areas and zip at speeds of the fastest Internet connection well beyond and above the standards. Computer technologies are the norm rather than the exception, and they become enablers rather than another subject to be taught in school.

Where are we in relation to this vision? After two decades of computers in classrooms we can say there have been some major strides. Most schools have computer labs; many schools have computers in every classroom. Over 90% of schools are wired (connected to the Internet), and over one-third of teachers have Internet access in their classrooms, which they and their students use frequently. Most teachers and students use word processing programs. We see teachers who use spreadsheets, simulations, CAD systems and multimedia software, but then again, we are especially tuned into looking and finding exemplars of technology use in schools. We know that a variety of factors predict whether and how teachers will use technology, including access, training, teaching philosophy, and collaboration with other teachers .

Still, broad statistics do not tell the whole story. Are computer technologies transforming classroom teaching and learning? Are they making it possible for students to achieve standards and go beyond? We don't have answers to these questions, yet we can report on some of the trends we see as a result of our work in the field.

IRL has been experimenting for many years with how technologies can leverage learning. In our projects we have spent much time introducing teachers to technology, developing technologies for content integration, and researching the process and practices of the teachers and students along the way. We have worked with a wide range of teachers, some of whom wanted to try computer technologies, and some who felt obligated to try. While we have seen many demonstrations of the content learning we know is possible, we have not seen large-scale adoption of technology in the core subject areas.

Even in schools where there is a strong push to adopt and use technologies, the road to content fulfillment is a long one. We see a pattern where the technology is front and center stage, rather than the academic content. In case after case we see that when computer technologies are adopted, the learning about the technology often takes over, and it is only after several rounds of integrating technology with content that content emerges in strong ways. The technology learning curve tends to eclipse content

learning temporarily - both kids and teachers seem to orient to technology until they become comfortable. This dilemma has important implications for teachers' willingness to adopt technology. This is because teachers in core subjects rightly see content, not technology, as the primary focus of their teaching efforts. Teachers' attention to content is important to pedagogy and usually leads to workable solutions.

The good news is that content learning does emerge and is very rich once the technology recedes as the focus of activities in the classroom. At its best, technology can facilitate deep exploration and integration of information, high-level thinking, and profound engagement by allowing students to design, explore, experiment, access information, and model complex phenomena.

Our research also indicates that while infusing technology into schools is worthwhile, it can be a long road from promise to reality.

- *Content integration takes time:* Teachers' first technology projects generate excitement, but often little content learning. Often it takes a few years until teachers can use technology effectively in core subject areas. Initially, teachers and students don't expect much content in technology projects and are satisfied if projects are completed and look good. Teachers learn to use computer technologies and learn how to bring content learning to the forefront with, in some cases, impressive results on the part of the students. Teachers eventually learn to view the learning process in concert with their new technologies and come to understand the ways content interactions can be approached.
- *Glitches galore:* The bumps in the road to technological competence almost guarantee that technology will take center stage over content at first. Inexperienced teachers tend to underestimate the time and complexity of a technology-based project. Software glitches and poor student work habits (e.g. forgetting to save work) can cause huge delays, often meaning that the project has to end just as students are starting to learn some subject matter.
- *Flash over substance:* Students and teachers alike are excited by the presentation capabilities of the new media, resulting in the "flash over substance" phenomenon. Over and over, we see that academic content is allowed to slide initially in a technology-infused project, as students spend their time exploring software capacity for special effects and animation.

Throughout this technology adoption process, teachers tend to worry about content, feel accountable for it, and notice when it is missing. This is a key dilemma in the technology adoption process. Teachers respond to this dilemma in at least three ways:

- *Back off:* Teachers diminish or stop technology use temporarily to make sure students accomplish content. This strategy has worked for teachers, but it usually means that computers, relegated to the sidelines, are employed for supplemental work, special projects, and skills and practice work rather than core subject matter.
- *Keep it simple:* With this strategy, teachers stick to one tried and true technology or use only the technology capabilities with which they are comfortable. With this strategy you might see a teacher encourage writing with word processing, using spreadsheets to make charts and graphs, or encouraging students to create reports using presentation software. The teacher might set goals for learning new software in the summers and plan to incorporate it in one project until a comfort level is reached. While this approach puts a floor on learning (students get some access to technologies), it can also impose a ceiling by limiting exploration and scope.

- *Dive in:* A third strategy is to plunge in head first with students using computer technologies, hoping that teachers and students will learn together about technology. Teachers who use this tend to have a lot of trust in their students' abilities to solve problems and find their way to subject matter. Sometimes this works, but often students and/or content falls through the cracks.

With the right support and access, all of these problems tend to recede as teachers and students gain experience with technology. Teachers learn how much to structure students' access to content. They develop effective assessment tools that help students focus on subject matter. Students come to understand the possibilities and expectations for learning with technology. Teachers and students both learn that different technologies offer different affordances and constraints in relation to what is being learned. They come to know that there are many ways to express subject matter with technology, and that technology won't (and doesn't need to) do the whole job.

To further embellish our characterization of this critical tension between technology learning and content learning, we offer cases from two of our projects. In both cases we have seen teachers handle the technology/content dilemma and move content leaning to the foreground of activities with computer technology.

The "Where's The Math?" Problem

We encountered these issues directly in our Middle-school Mathematics Through Applications Project (MMAP). One of MMAP's accomplishments was that it found a working balance between content learning and engaging with technology that made it possible for many students to achieve middle school math standards. In our description we aim to reveal what occurred between the onset of the content crisis recognition to the achievement of true integration.

The MMAP project created technology-integrated environments where students could participate in mathematics learning through designing solutions to real-world problems. The students role play architects, population biologists, encryption experts, and analysts of geographic databases who are asked to design solutions for various clients. They are equipped with many adult-like computer and mathematical tools. We developed and field-tested four software environments and related design-based curriculum units. Our first software environment was ArchiTech, a mini-CAD system where students could design a floor plan for a structure, manipulate certain variables relating to indoor and outdoor temperature and building insulation values, calculate area, perimeter and heating and building costs, and analyze the data to make design decisions. We designed the program to be a simple and easy to use. It can run on any computer that a school might have. Our hypothesis was that if the software was simple to learn and easy to use, teachers and students would be able to enjoy the environment and concentrate fully on the mathematics and design tasks presented in the units.

We wrote a curriculum unit called *The Antarctica Project* where students design a research station for scientists who are going to work in Antarctica. Before releasing the unit into classroom field tests, we ran through the unit with our staff, as well as a group of 16 local middle school teachers who worked with us over the course of the project, and small groups of middle school students. All learned how to use the program quickly and were engaged in the mathematical work as we had hoped. Even teachers who were skeptical were impressed with the amount and sophistication of the mathematics that they found themselves engaging with as they worked through the design project. They were also impressed with how engaging the software was. Our videotapes and observations of these formative trials were

confirming as well. The Antarctica unit was written with a notion that teachers would easily (almost naturally) identify and track when the time was right to introduce new mathematics concepts, activities, skills, or next project steps. Math opportunities would emerge from the designs students created in ArchiTech, which would be a focal point around which mathematical engagements, activities, and conversations would develop. We hoped that the mathematics would be obvious and ubiquitous.

The rough and tumble life of classrooms revealed a different reality. While teachers and students were engaged, on task, excited and involved with the ArchiTech environment and with the design of the research center, it seemed to both teachers and students that they had "fun" with the software and design task, but ignored their mathematics work. The students told us they loved their new math class, because it was fun to use the computers and great to pick up real life architectural skills. When asked if they were learning any math, they looked blankly at us, "No math, but we're learning about the real world." Back with the videotapes at IRL, we found students wrestling with scale and proportion problems related to their research center designs for thirty minutes at a time. They also analyzed the complex relationships among variables in their designs, such as the costs of heating and the insulation values. But the students could not identify the math or depict themselves being mathematical, and the teachers were uncertain about what math was actually accomplished by the students in the groups. By the time we analyzed the tapes and described the math, it was, relative to classroom realities, irrelevant. We asked the question, "Is math really being accomplished if no one in the classroom can see it?" Our answer was "No."

We had a crisis on all levels. The software seemed to be doing its job. It was easy to learn, easy to use, engaging to all of the students and provided many opportunities for mathematical content engagement. On videotape, we could find children working hard during group time yet reporting they did "nothing" mathematically. In project presentations, most students presented lists of rates and costs of specific design variables. When we questioned students we found they were capable of talking in quite detailed ways about the math they had accomplished and used many representations of their ideas in their explanations to us. In general, the students had extremely limited ideas about what constituted mathematics, and we decided the problem wasn't only about technology presence. We realized we had gotten deep engagement with the technology and gloss engagement with mathematics content. The teachers lamented that even though they would sometimes have remarkably complex math conversations with children, they were hard pressed in meetings with parents to say what the children had learned. Imagine the students telling their parents that math class was great because they had fun playing on the computers, and they were learning what it was like to be architects, even though they didn't do any math.

This pattern was repeated in a second classroom. Both teachers were enthusiastic and committed to doing the project the next year. We considered taking a wait-and-see attitude on how the content would play out the second time around. However, being a mathematics project, we felt we should alter the approach to mathematics content to force a balance. A much higher level of productivity for both teachers and students on the mathematics front was needed. We turned our attention to strengthening the unit activities by structuring problems with systems of constraint, and embedding specific unit activities and assessment tools for enhancing mathematics participation. A variety of activities was added that structured students' noticing, naming, further developing and reflecting on the math they encountered in their project design work. We also helped teachers make more productive use of their informal conversations with students. We found that by encouraging teachers to slow down and spend a few minutes with each group, they were able to let students describe their designs, discuss issues or problems, interrogate around relevant math topics, and suggest next steps.

We saw much more balance after consciously marrying the technology environment to the content. Students still engaged with each other, the computer environment and with the mathematics at deep levels. Students still felt they were learning how to use important, adult-like tools, learning about adult work and problem-solving, yet they also knew they were learning about scale and proportion and using and relying on representations of function and variable while making design decisions.

The message: Activity structure is one way to mediate the interplay between engagement with content and immersion in technology environments, so that content is not relegated to the background. Computer technologies, like other technologies, are powerful tools for accessing complex mathematical ideas and concepts. Technologies can be extremely powerful, provided we take the time to embed them in content-rich activities.

The Challenge 2000 Multimedia Project

We have addressed similar issues in our work with teachers in the Challenge 2000 Multimedia Project. This project has a seven-component model for project-based learning using multimedia that has been successful in helping teachers juggle the multiple demands of developing students' subject-matter knowledge while teaching technology and collaboration skills. The model suggests that students engage in multi-media-supported projects that have these seven characteristics:

1. Anchored in core curriculum; multidisciplinary
2. Involves students in sustained effort over time
3. Involves student decision-making
4. Involves students in collaborative work
5. Has a clear real-world connection
6. Incorporates systematic assessment throughout the project
7. Takes advantage of multimedia as a communication tool

The fact that only one of the seven characteristics specifically mentions technology attests to the inseparability of curriculum, pedagogy, and media in the successful use of technology for learning. Successful technology projects need much more than good technology.

In particular, the improved content learning in Challenge 2000 Multimedia classrooms has been supported in at least three ways:

- extensive teacher professional development support
- ongoing assessment of student work - in progress and at project-wide exhibition events
- patience - allowing time for students and teachers to reach proficiency sufficient for high-quality multimedia-based learning

How do these factors interact with teachers as they try to use technology and uphold their responsibilities to help students learn appropriate content and related disciplinary practices (such as historical research)? To find out, we'll look at the experiences of two Challenge 2000 teachers during the 1998-1999 school year.

Views from the field: Two teachers' experiences

Greta Barstow is a middle school history teacher and a teacher/leader in the Challenge 2000 Multimedia

Project. Oscar Jarret teaches a mixed fourth and fifth grade class and is one of the Challenge 2000 project teachers. Both are experienced teachers and technology users who have implemented multimedia projects in their classrooms and have been with the Challenge 2000 Project for several years. With a certain amount of technological mastery, each responded enthusiastically to the idea of improving the content in students' multimedia projects this year. Both decided to do this in part with greatly-increased formative assessment to help focus students on the content in their projects. As Ms. Barstow told her history class, "This is a history class, not a computer class. So I'm going to be looking for evidence that you learned some history in this project."

Ms. Barstow's project was for students to develop a virtual museum on the web that would help visitors learn about Chinese history through Chinese art. Students worked in small groups, with each group focusing its work on one Chinese dynasty. They developed HyperStudio stacks (later ported to the web) with photographs of artwork from the dynasty, related poems and text about history, religion, and culture depicted in the artwork. The stacks also contained photographs of art replicas the students had made themselves.

Ms. Barstow developed a series of handouts titled "Is My Project Good?" This was a question students kept asking her, and she wanted them to learn to answer it on their own. To do this they would critically look at their own work with their teacher, with peers, and alone. The handouts asked students to answer questions such as, "What connections did I make between art and other aspects of Chinese culture?" "Is the information written in my own words, in an interesting way so that my peers will enjoy reading it? If not, what do I need to change/add?" As the versions of "Is My Project Good" evolved, she made the questions more specific and scheduled more opportunities for students to assess by using the forms. For example, with the first form she asked each group to present their in-progress HyperStudio stacks to the class for comment. With the second, she conferenced with each group as they worked to answer the assessment questions together. Formative assessment continued throughout the project. The results were impressive; the content in student projects far surpassed her expectations based on work done earlier in the year, as well as in comparison to projects her students had produced in previous years. She was particularly pleased with the progress made by the class she considered to have the weakest skills.

Still, despite her focus on content and experience in technology, Ms. Barstow experienced many setbacks and frustrations. She experienced:

- *Competition for resources*: Many teachers schedule technology projects for the end of the year, and everyone needed the computer lab at once. Ms. Barstow only got one week of computer time, and for the rest of the project, students had to take turns using the one computer in her classroom.
- *Pressure to cover the curriculum:* As is common for teachers with a large amount of curriculum to "cover", she fell behind as the school year drew to a close. She felt pressure to bring the project to completion and move on, even though many students would have benefited from more time.
- *Insufficient student research skills:* Ms. Barstow was pleased to see students noticing missing content in their projects and begging for library time to find more. Her pleasure turned to disappointment when she saw that her students' research skills were often too low for them to find the information they needed. Although she tried to supplement skills as problems came up, time was too short for her to make much progress.
- *Inefficient technology use:* Students tended to fall into very labor-intensive methods for getting their information into the computer. For example, they entered text in a way that made it almost impossible to edit without completely retyping it. Then, when students decided to revise, they had

to spend precious computer time retyping long blocks of text. It was almost unbelievable how long simple changes could take - a whole class period to reorganize one screen.

In another school, Mr. Jarret was experiencing his own set of triumphs and frustrations as his fourth and fifth graders worked on their Habitat project. They created an on-line guide to habitats they had visited. Earlier in the year, they had made huge dioramas of these habitats with paper mâche animals, plants, and posters that told about the animals, their place in the food pyramid, and their life cycle. Now they photographed their dioramas, did additional research, and created web pages about each animal and habitat. This web-based multimedia project was one of three the class was working on concurrently. There was also a project about artists and another about a class project based on the work of the artist Hokusai.

Mr. Jarret tried to support student learning in three areas: content, collaboration, and use of multimedia. These are the areas judged at the Challenge 2000 Student Interviews and defined in the Challenge 2000 Multimedia Rubric. Mr. Jarret scheduled a series of assessment events during the project to help students come to a consensus on what it meant to have good content and multimedia and to collaborate well. For example, he scheduled two whole-class design reviews. Students used a rubric that they had developed, based on the Challenge 2000 Multimedia Rubric, to critique their classmates' works-in-progress. They asked such questions as, "Is the work organized? How might they make it even more organized?" In this way the class developed a sense of what it meant to have a web page be organized. They spent a lot of time putting themselves in the shoes of imagined web page viewers, and deciding if such a viewer would be able to understand the information and would want to keep looking at the site.

The assessment events were very effective in helping students orient to the audience outside their classroom - once their work was on the web, anyone might see it. Several students gave this as a reason why they did additional research on their projects. Assessment events also helped students see how they could use photographs, drawings, and text together to express what they knew about their habitats and animals. Because of the concurrent work on collaboration skills, students were able to work efficiently and independently away from the teacher. Mr. Jarret gave them a small set of technology tools and procedures for doing the work, and once these were mastered, students used them in a fairly uniform way to get the work done and create the web site. They could concentrate on content and organization without too much attention to technology. They used Adobe PhotoShop to edit and size content elements such as photographs, scanned drawings and maps. They used Claris Homepage to create tables with the content elements they had edited in PhotoShop and descriptive text. Mr. Jarret pointed out particular tools and procedures in each program (e.g. setting the background color in a table cell, setting the text color and size, importing a JPEG picture). Students who became technology helpers used these tools and developed procedures for their work until they could help each student organize his or her page in a short time. Each student became a content expert on his or her animal, and designed and index-card based storyboard to prepare for making the web page. As the deadline of the Multimedia Fair approached, the class became an efficient working group and churned out several pages a day. All in all, the project went smoothly.

Still, there were frustrations related to:

- *Learning the technology:* This was the first time Mr. Jarret had done a web site project, even though he had done many HyperStudio and PowerPoint projects before. He had to learn the technology almost concurrently with his students. Some work had to be redone as the class came upon some unexpected limitations of the methods that Mr. Jarret knew to link pages together. This points to the difference between the level of learning a teacher gets in a training session and the

complications of real technology use in a big project.

- *Running out of time:* Mr. Jarret felt that the time spent in assessment and preparatory work was valuable, but it meant that little time remained to get the sites done before the district Multimedia Fair. In the end, a few parent volunteers spent a long night before the Fair checking and linking pages.
- *Keeping it too simple?* Mr. Jarret felt that he had to limit what students put on their web pages to the kinds of media he knew how to use. There was little time for experimentation. Therefore nobody used sound or animation. Pages all were built the same way - as tables. Mr. Jarret felt that this was unavoidable if the project was ever going to get done.

Learning from classroom experience

These classrooms seem like some of the busiest places on earth. A computer crashes and students explode with frustration. A group gets an animation working - everyone crowds around to see. There's a line in front of the scanner. Kids leaf through books looking for just the right picture. The teachers alternate between resetting the printers, looking for more paper, calling the library to see if students can get in, and helping students understand content.

We can see why it is so important for teachers to be able to network with other teachers. So many different problems come up during a project that there is no way a teacher can completely prepare in advance. Teachers need sources of just-in-time advice. Each emergent problem, once solved, becomes a tidbit of knowledge that might just save another teacher a few days of frustration.

The two teachers' stories show that even fairly experienced teachers struggle to balance content integration with available time and resources. Even experienced teachers have to learn new technology, because it is always changing. They also have to find ways to make a technology project teach enough in terms of the subject matter to make it worth the time it takes.

Yet, like the middle school math teachers, both of these teachers can hardly wait for the next year, so they can put to work all the insights and skills they acquired during these projects. Ms. Barstow wants to spend more time conferencing with groups. Mr. Jarret wants to develop templates for students so that they can start their projects at a higher level of technology use. Both were excited about the way their students learned content, and also learned to manage time, collaborate, design, and use new software.

Capitalizing on the Tension of Integrating Technology

The dilemma of learning both computer technology and content exists and will continue to persist. There will always be new computer technologies to learn and there will always be new ways to approach the learning of content. In fact, the problem is a wonderful paradox because technologies have made it possible for many teachers to see that complex ideas and abstractions-the parts of content learning that seem so difficult for students to accomplish-are actually made more accessible through the use of computer technologies. Teachers are seeing that classroom content can be more than assembling pieces of knowledge to be learned, and that technology can offer representations, visualizations, and interactions that really help students negotiate concepts and abstractions. Conceptions of what should be taught and how it can be taught are now in flux, and computer technologies are playing a role in demonstrating how subject area standards can be realistic and accessible for students. Teaching is complicated and computer technologies, like other technologies that came before, create affordances and constraints in the learning

process. In both MMAP and the Challenge 2000 Multimedia Project, teachers are working to reconceive their approaches to content as well as their approaches to the media, tools and classroom and virtual activity structures. As always, this process is at the heart of teaching. Teachers from both projects have explained how integrating technology into their classrooms has brought a revitalization to their teaching. They are no longer using the same materials year after year, and they feel that they are getting to learn alongside their students.

The technology learning/content learning dilemma necessitates a call for more complex models and experiences for teacher professional development and more materials that support standards-based learning. Our work at IRL has centered around creating materials and helping teachers create formal and informal opportunities for networks and communities in which to learn technologies and to work on these teaching dilemmas. We advocate for teachers to have time to experiment with technologies, share best and worst practices, study exemplars of student work, and deal with conflicts, successes and disappointments in their attempts with computer technologies. Once teachers have engaged with technology and have seen students engage, shine and go beyond their expectations, they are willing to cope with the tension between attention to technology and attention to content. They need to carve out time and become proficient at being in a classroom that feels like the busiest place on earth while staying focussed on pedagogy. It's a tall order, but we are seeing more and more teachers succeeding.

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